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FLUX LOSS DURING THE FORMATION OF FRC

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One important feature of FRC formation is the loss of the reversed flux. In this note we present the results of simulations that are intended to study this loss.

A hybrid simulation[1,2] in which the ions are kinetic while the electrons are an inertialess, charge neutr lizing fluid, is necessary when studying implosions in experiments such as FRX-' because of the presence of ion beams reflected off the magnetic piston. The presence of such kinetic features makes a fluid description questionable for the ions. Such a feature is illustrated in Fig. 1, in which a $v_r - r$ cut of the ion phase space during an FRX-B implosion is presented.

The electron momentum equation implies an ohms law for the evolution of the magnetic fields. However, an electrical conductivity must be specified. By an appropriate specification, the influence of electron inertia, change separation, microturbulence, etc. may be approximately included. We use a formula [1,2] which has successfully described many theta pinch and reversed field pinch experiments.

We first simulate an FRX-B implosion in which the initial density $n_o = 1.1 \times 10^{15} cm^{-3}$, $T_{eo} = T_{io} = 4ev$, $B_o = 1.2kG$ and initial trapped flux $\phi_o = \pi R^2 B_o = 4.5 \times 10^8 G\ cm^2$. The trapped reversed flux at any subsequent time, $\phi(t)$, is the flux enclosed between the geometric axis and the cylinder on which the field null occurs. Figure 2 is a plot of $\phi(t)/\phi_o$. The $\times$ with error bars are experimental measurements, the lower curve is a simulation with anomalous resistivity, and the upper curve is a simulation with classical resistivity.

The curve calculated with classical resistivity is above the experimental points, 2.5 μs, while the curve calculated with anomalous resistivity is consistent with the data. The implications are that classical resistivity alone is insufficient to explain the data. The flux is lost anomalously fast. The anomalous resistivity algorithm used is adequate to explain the observed loss, although a slightly better fit might be obtained by slightly lowering the strength of the anomalous contribution.

After the imploding sheath has past a point near the wall, the plasma initially there is swept up and the density there is very low. The numerical algorithm does not represent this low density region well, so that additional assumptions must be made to model it. We have considered two possible models for the region. One is that vacuum fields are present, and another is that the tenuous plasma can carry a nonnegligible current. In Fig. 2, field profiles at 1.25μs are plotted. The × are the experimental data, the dotted line is the simulation with the vacuum field assumption, and the solid line is the simulation with the tenuous, current carrying, plasma assumption. The latter assumption is clearly a better representation of the data.

When the resistivity is anomalous, the question of the division of the joule heating among the various species must be addressed. Microinstabilities, such as the lower hybrid drift,[3] which generate the anomalous resistivity, can also cause the anomalous ion heating. If the regime near the wall is assumed to contain a low density, current carrying plasma and if all the joule heating is deposited in the electrons, $\langle T_i \rangle \sim 50$ ev at 2.5 μs, compared with the measured value of 500 ev at 5μs. Evidently, the computed ion heating rate is too low. If, however, 50% of the joule heating is given directly to the ions, $\langle T_i \rangle \sim 200$ ev at 2.5μs. This heating rate is sufficient to match the data.

Perhaps the most important question to address when studying the issue of reversed flux loss during the implosion is how to minimize it. We have varied several of the initial and boundary conditions and found the loss to be insensitive to most parameters. The one parameter that did influence it was the initial bias field. In particular, $\phi(t)/\phi_o$ increased as $|B_{bias}/B_{wall}|$ increased. When $|B_{bias}/B_{wall}| = 0.04$, $\phi(t)/\phi_o = 0.15$ after the first bounce while if $|B_{bias}/B_{wall}| = 0.21$, $\phi(t)/\phi_o = 0.38$. Thus, as $|B_{bias}/B_{wall}|$ increases, both $\phi_o$ and $\phi(t)/\phi_o$ increase. However, if $|B_{bias}/B_{wall}|$ is made too large, the CT will not form properly. Thus, there must be an optimum value for it and we are presently searching for this value.

In conclusion, the field profiles and the evolution of the trapped flux as a function of time imply that the resistivity is anomalous and that a tenuous plasma between the CT and the wall carries a nonnegligible fraction of the current. About half of the anomalous joule heating is deposited directly to the ions. The fractional flux retention increases with increasing $|B_{bias}/B_{wall}|$, up to some optimum value.

## References


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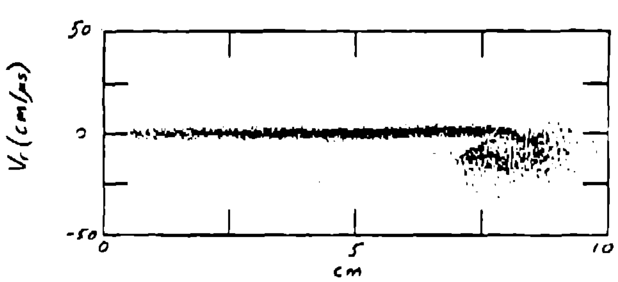


Figure 1

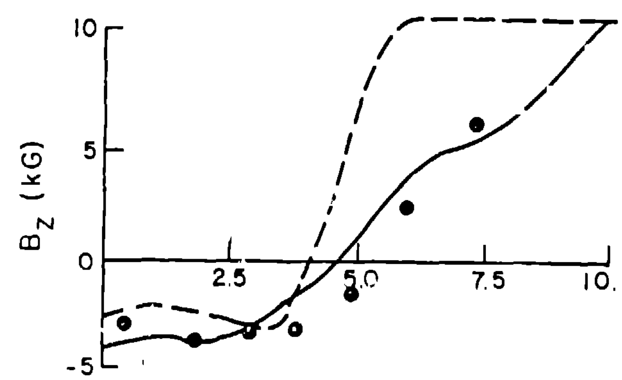


Figure 2

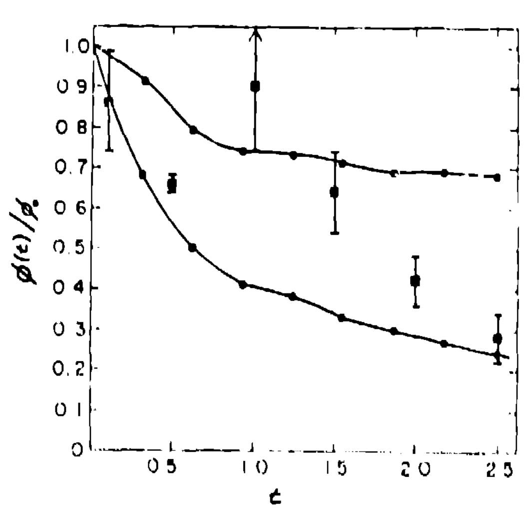


Figure 3